Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/US04/041164

International filing date: 01 December 2004 (01.12.2004)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 60/527,895
Filing date: 05 December 2003 (05.12.2003)

Date of receipt at the International Bureau: 17 January 2005 (17.01.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

1271237

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APPLICATION NUMBER: ***60/527,895***
FILING DATE: ***December 05, 2003***
RELATED PCT APPLICATION NUMBER: ***PCT/US04/41164***

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Jeff	Cooper	Rocky Hill, New Jersey
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☒ *Additional inventors are being named on the* 1 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

FILM GRAIN SIMULATION AND COMFORT NOISE ADDITION SPECIFICATION FOR DIRECTV A3 SYSTEM

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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ENCLOSED APPLICATION PARTS ***(check all that apply)***

☒ Specification *Number of Pages* 18 ☐ CD(s), Number ____

☐ Drawing(s) *Number of Sheets* ____ ☐ Other (specify) ____

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☐ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees

☒ The Director is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 07-0832

☐ Payment by credit card. Form PTO-2038 is attached.

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☐ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: ____.

[Page 1 of 2]

Respectfully submitted,
SIGNATURE ____

Date 12/5/03

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Docket Number: PU030308

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17548 U.S. PTO
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PTO/SB/16 (08-03)
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Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Docket Number PU030308

INVENTOR(S)/APPLICANT(S)

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☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 160

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Jeff Cooper
Examiner Name	
Art Unit	
Attorney Docket No.	PU030308

METHOD OF PAYMENT *(check all that apply)*

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Deposit Account Number: 07-0832

Deposit Account Name: THOMSON LICENSING INC.

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	770	2001	385	Utility filing fee	
1002	340	2002	170	Design filing fee	
1003	530	2003	265	Plant filing fee	
1004	770	2004	385	Reissue filing fee	
1005	160	2005	80	Provisional filling fee	160

SUBTOTAL (1) ($) 160

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims	-	** =	0	X		=	0
Independent Claims	-	** =	0	X		=	0
Multiple Dependent				X		=	0

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0

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FEE CALCULATION (continued)

3. ADDITIONAL FEES

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1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet.	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	420	2252	210	Extension for reply within second month	
1253	950	2253	475	Extension for reply within third month	
1254	1,480	2254	740	Extension for reply within fourth month	
1255	2,010	2255	1,005	Extension for reply within fifth month	
1401	330	2401	165	Notice of Appeal	
1402	330	2402	165	Filing a brief in support of an appeal	
1403	290	2403	145	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive – unavoidable	
1453	1,330	2453	665	Petition to revive – unintentional	
1501	1,330	2501	665	Utility issue fee (or reissue)	
1502	480	2502	240	Design issue fee	
1503	640	2503	320	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17 (q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	770	2809	385	Filing a submission after final rejection (37 CFR § 1.129(a))	
1810	770	2810	385	For each additional invention to be examined (37 CFR § 1.129(b))	
1801	770	2801	385	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) ____

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 0

SUBMITTED BY Complete *(if applicable)*

Name (Print/Type)	Robert B. Levy	*Registration No. (Attorney/Agent)*	28,234	*Telephone*	609-734-6820
Signature				*Date*	December 5, 2003

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Film Grain Simulation and Comfort Noise Addition Specification for DirecTV A3 System

1 INTRODUCTION

This document provides a specification for film grain simulation and comfort noise addition in a DirecTV A3 system.

The film grain simulation is based on the contribution JVT-I013r2 [1] adopted at the 7th JVT meeting. Constraints of the DirecTV system regarding the value of the parameters of the SEI message and some implementation aspects are described.

Comfort noise addition reuses hardware elements of the film grain simulation to hide compression artifacts.

2 FILM GRAIN SIMULATION

2.1 FILM GRAIN SEI Message Constraints

The film grain generator makes use of the parameters specified in the SEI message described in [1, 2]. Limitations regarding the SEI message are described.

Film grain SEI messages may only be sent preceding I pictures, and only one film grain SEI message may precede a particular I picture. I pictures are indicated by slice_type equal to 7, or by nal_ref_idc equal to 5.

`model_id` shall be 0. This identifies the film grain simulation model as frequency filtering.

`colour_space_id` shall be 0. This identifies the color space in which the parameters of the SEI message have been estimated as YCbCr.

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blending_mode_id shall be 0. This identifies the blending mode used to blend the simulated film grain with the decoded images as additive.

log2_scale_factor shall be in the range [2, 7].

comp1_param_present_flag shall be 0. This prevents the transmission of film grain parameters for the Cb color component.

comp2_param_present_flag shall be 0. This prevents the transmission of film grain parameters for the Cr color component.

no_intensity_intervals_minus1[0] shall be in the range [0, 7]. This gives the number of intensity intervals for which a specific set of parameters has been estimated.

intensity_interval_lower_bound[0][i+1] > **intensity_interval_upper_bound[0][i]** for i=0…6. This indicates that multi-generational film grain is not supported.

no_param_minus1[0] shall be in the range [0,2]. Low-pass modeling and cross-color correlation are not used.

param[0][i][0] shall be in the range [0, 255].

param[0][i][1] shall be in the range [3, 15].

param[0][i][2] shall be in the range [3, 15] and shall be transmitted only when not equal to param[0][i][1]. When both parameters are transmitted, ~~the allowed~~ only the pair of values ~~are~~ listed in Table 1 are allowed.

param[0][i][1]	param[0][i][2]
4	3
6	4
7	5
8	6
10	7
11	8
13	9
14	10
15	11

15	12
15	13
15	14
15	15

Table 1.

All the other parameters of the SEI message have no constraint with respect to the standard specification.

2.2 Film grain Implementation aspects

Film grain addition involves two distinct steps of operation. First, an initialization process is performed when an SEI message is received preceding an I picture, in which a pool of film grain blocks is created. Then, prior to display, a simple process is applied to add the stored film grain blocks to each luma pixel of each decoded picture.

2.2.1 Initialization at SEI message receipt to create film grain block pool

Upon receipt of a film grain SEI message, an initialization process is performed to create a pool of 4,096 (512x8) film grain pixel values for each of up to 8 different luma intensity intervals. The number of luma intensity intervals is indicated by 1 plus the SEI message field **`no_intensity_intervals_minus1[0]`**. Generation of the film grain samples begins with the lowest luma intensity interval.

Bit-accurate simulation of the film grain noise can be accomplished using a specified uniform pseudo-random number generator polynomial and using a specified database of film grain patterns. The database of film grain patterns is composed of 13 sets of 4,096 (512x8) values each. The values are stored in 2's complement form and range from [-127, 127]. The list of values for each set is shown in the Appendix.

The process to obtain the film grain pixel values for a particular luma intensity interval s is shown in the block diagram of Figure 1. The process specifies the access to the database of film grain patterns, the scaling of the values, and their storage into the pool as follows:

for(i = 0..4,095)
    v = param[0][s][0] * database[m][n][i]
    pool[s][i] = $(((v + 2^{\text{log2\_scale\_factor} - 1}) >> \text{log2\_scale\_factor}) + 32) >> 6$

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where n is equal to param[0][s][2] – 3, m is equal to 0 when **no_param_minus1[0]** is 1 and equal to 1 otherwise, and the factor 6 scales the film grain values provided in the Appendix.

This process is performed as many times as indicated by 1 plus the SEI message field **no_intensity_intervals_minus1[0]**.

2.2.2 Block and pixel operations prior to pixel display

The operations performed to add film grain to the decoded picture at block and pixel level are shown in Figure 2. For each 8x8 block of the decoded image, the average of the luma pixel values is computed and compared to the SEI message **intensity_interval_lower_bound[0][i]** and **intensity_interval_upper_bound[0][i]** parameters to determine the correct luma intensity interval for the block.

A uniform random number generator, using a primitive polynomial modulo 2 operator, $x^{18} + x^5 + x^2 + x^1 + 1$, is used to select film grain blocks from the pool. Let x(i, e) indicate the i-th symbol of the sequence x, beginning with an initial seed e. (The seed is set to 1 upon the receipt of each film grain SEI message.) The offset for the current 8x8 block of film grain is generated as follows:

```
previous_offset = offset
offset = (x(i, 1) % 4,088 )>> 2
offset ^= (index == previous_offset)
offset <<= 2
```

where offset has been initialized to 0 after the creation of the pool. After the calculation of the offset, the 8x8 block of film grain is extracted from the pool as follows:

```
for (i = 0..7, j = 0..7)
        block[i][j] = pool[s][offset + i + j*4096]
```

Before blending the film grain block with the decoded image, deblocking of the pixels on the left and right columns of the block is performed as described in Section 2.2.2.1. The deblocked film grain block is then added to the decoded pixels and the result clipped to [0, 255] for display. Film grain noise is only added to luma pixels.

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2.2.2.1 Deblocking filter

As suggested in [1], a deblocking filter shall be applied on the film grain image before blending to smooth the blocking artifacts resulting from the small size of the transform. The deblocking filter is implemented by means of a 3-tap filter applied to all pixels bordering the 8x8 block left and right edges. Given a row of pixels belonging to two adjacent 8x8 blocks, the transition between blocks being located between pixels b and c,

						a	b	c	d						
			Block A									Block B			

the filter is applied as follows:

$$b' = (a + (b \ll 1) + c) \gg 2$$
$$c' = (b + (c \ll 1) + d) \gg 2$$

where b' and c' replace the value of the original pixels b and c, respectively. Deblocking of the left and right block edges is done for every block at display time.

3 COMFORT NOISE SPECIFICATION

Comfort noise addition is used to hide compression artifacts. Comfort noise addition and film grain simulation are not used at the same time. Unlike film grain simulation, it is not intended to match a pre-specified noise pattern (i.e. film grain).

A custom SEI message is proposed to enable turning comfort noise on and off, as well as indicating the level of noise to add, based on the expected level of compression artifacts.

Comfort noise addition utilizes several of the film grain simulation hardware elements.

3.1 Comfort noise SEI message

We propose use of a registered user data SEI message to indicate the use of comfort noise. It applies to all pictures that follow, until an IDR or a new comfort noise or film grain SEI message arrives. Comfort noise SEI messages may only be sent preceding I pictures, and only one

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comfort noise SEI message may precede a particular I picture. I pictures are indicated by slice_type equal to 7, or by nal_ref_idc equal to 5.

user_data_registered_itu_t_t35(payloadSize) {	C	Descriptor
itu_t_t35_country_code	5	b(8)
itu_t_t35_payload_byte	5	b(8)
comfort_noise_flag	5	u(1)
if (comfort_noise_flag == 1) {		
comfort_noise_qp_offset_idc	5	ue(v)
comfort_noise_qp_weight_offset_idc	5	ue(v)
}		
}		

comfort_noise_flag equal to 1 indicates that comfort noise addition is used.
comfort_noise_flag equal to 0 indicates that comfort noise addition is not used.

comfort_noise_qp_offset_idc indicates the quantization parameter offset used in the calculation of the additive comfort noise level, and may range in value from –51 to 52.

comfort_noise_qp_weight_offset_idc indicates a quantization parameter weight offset used in the calculation of the additive comfort noise level, and may range in value from –6 to 7.

3.2 Comfort noise implementation aspects

Comfort noise addition includes operations performed at the block level, and operations performed at the pixel level. A key difference between film grain and comfort noise is the temporal correlation of additive comfort noise.

3.2.1 Block level operations

Per block operations are performed to calculate relative weights of the three terms used for comfort noise generation, as shown in Figure 3. The inputs to this process are decoded luma

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pixels, the picture QP = (**pic_init_qp_minus26** + 26), and the **comfort_noise_qp_offset_idc and comfort_noise_qp_weight_offset_idc** from the comfort noise SEI message.

The current picture number is indicated by t. t is reset to 0 for the I picture that follows a comfort noise SEI message. The average of the 8x8 luma pixel block of the current picture, t, is calculated as block_avg(t) and compared to a threshold. If block_avg(t) ~~>~~≤ 10, block_avg_level = 1, otherwise block_avg_level = 0.

The absolute difference of the current luma block average with respect to the co-located block from the previous displayed picture is calculated, where t-1 indicates the previous displayed picture, and compared to a threshold. If |block_avg(t) – block_avg(t-1)| > 3, block_absdiff_level = 0, otherwise block_absdiff_level = 1. If t is equal to 0, block_absdiff_level = 1.

For SD resolutions and below, all pixel and block operations are done using the display resolution. For HD resolutions, block operations are performed using 2x2 sub-sampled pixels (using the upper left pixel of 2x2 pixels), so the 8x8 luma pixel avg involves adding 8x8 = 64 pixel values, but these values are spread over a 16x16 pixel range. For SD resolutions, storage of the block_avg values for the entire picture requires storage of 1/64 the size of a frame store. For HD resolutions, storage of block_avg values requires a storage of 1/256 the size of a frame store.

The values of **comfort_noise_qp_offset_idc**, **comfort_noise_qp_weight_offset_idc**, and picture QP, are used in the calculation of an *intermediate* weight w_q which is calculated as follows:

w_q = (clip((weight (clip(QP +**comfort_noise_qp_offset_idc**,0,51)) + **comfort_noise_qp_weight_offset_idc**),0,7)

where weight(Q) is defined in Table 2~~Table 1~~.

Q	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
weight(Q)	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*
weight(Q)	0	0	0	0	0	0	0	1	1	1	2	2	2
Q	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*
weight(Q)	3	3	3	4	4	4	4	4	4	4	5	5	5
Q	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*
weight(Q)	5	5	5	5	5	5	5	6	6	6	6	6	6

Table 2~~1~~. weight(Q) lookup table

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The value of w_q, which needs to be computed only once for each picture, and the values of block_avg_level and block_absdiff_level are then input to a lookup table to find the values of the final weights, w_0, w_1, and w_f, which are used in the pixel level operations.

w_q	block_absdiff_level	block_avg_level	w_f	w_1	w_0
0	0	0	0	0	0
	0	1	0	0	0
	1	0	0	0	0
	1	1	0	0	0
1	0	0	12	11	25
	0	1	12	8	19
	1	0	30	10	14
	1	1	30	7	11
2	0	0	23	22	50
	0	1	23	17	38
	1	0	60	20	28
	1	1	60	14	21
3	0	0	35	34	76
	0	1	35	25	57
	1	0	90	29	42
	1	1	90	21	32
4	0	0	47	45	101
	0	1	47	34	76
	1	0	120	39	56
	1	1	120	28	42
5	0	0	59	56	126
	0	1	59	42	95
	1	0	150	49	70
	1	1	150	35	53
6	0	0	70	67	151
	0	1	70	50	113
	1	0	179	59	84
	1	1	179	42	63
7	0	0	82	78	176
	0	1	82	59	132
	1	0	209	69	98
	1	1	209	49	74

Table 32. Lookup table for comfort noise generation.

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Note that the determination of the current picture structure is based on display rather than coding structure. For interlaced display, pixels from the current field and previous field are used in the calculations. For progressive display, pixels from the current frame and previous frame are used in the calculations.
~~The values of block_avg_level and block_absdiff_level are input to a lookup table to find the values of sw_0, sw_1 and sw_f.~~

~~0~~	~~0~~	~~9~~	~~16~~	~~36~~
~~0~~	~~1~~	~~9~~	~~12~~	~~27~~
~~1~~	~~0~~	~~23~~	~~14~~	~~20~~
~~1~~	~~1~~	~~23~~	~~10~~	~~15~~

~~Table 2. Lookup table~~

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~~These values { sw_0, sw_1, sw_f } and the values of the picture QP, **comfort_noise_qp_offset_idc**, and **comfort_noise_qp_weight_offset_idc** are then used in the calculation of the final weights, w_0, w_1 and w_f, which are used in the pixel level operations.~~

Q	0	1	2	3	4	5	6	7	8	9	10	11	12
weight(Q)	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	13	14	15	16	17	18	19	20	21	22	23	24	25
weight(Q)	0	0	0	0	0	0	0	1	1	1	2	2	2
Q	26	27	28	29	30	31	32	33	34	35	36	37	38
weight(Q)	3	3	3	4	4	4	4	4	4	4	5	5	5
Q	39	40	41	42	43	44	45	46	47	48	49	50	51
weight(Q)	5	5	5	5	5	5	5	6	6	6	6	6	6

~~Table 3. weight(Q) lookup table~~

~~With weight(Q) defined in Table 2,~~

~~w_q = (clip((weight (clip(QP + **comfort_noise_qp_offset_idc**,0,51)) + **comfort_noise_qp_weight_offset_idc**),0,7)~~

~~$w_0 = sw_0 * w_q$~~
~~$w_1 = sw_1 * w_q$~~
~~$w_f = sw_f * w_q$~~

~~**The** above multiplies could be completely avoided **if implemented with the use of a larger lookup table** that also considers the value of w_q, and which can immediately compute w_0, w_1, and w_f **without** the intermediate calculations of sw_0, sw_1, and sw_f.~~

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0	0	0	0	0	0
	0	1	0	0	0
	1	0	0	0	0
	1	1	0	0	0
1	0	0	9	16	36
	0	1	9	12	27
	1	0	23	14	20
	1	1	23	10	15
2	0	0	18	32	72
	0	1	18	24	54
	1	0	46	28	40
	1	1	46	20	30

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3	0	0	27	48	108
	0	1	27	36	81
	1	0	69	42	60
	1	1	69	30	45
4	0	0	36	64	144
	0	1	36	48	108
	1	0	92	56	80
	1	1	92	40	60
5	0	0	45	80	180
	0	1	45	60	135
	1	0	115	70	100
	1	1	115	50	75
6	0	0	54	96	216
	0	1	54	72	162
	1	0	138	84	120

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	~~1~~	~~1~~	~~138~~	~~60~~	~~90~~
~~7~~	~~0~~	~~0~~	~~63~~	~~112~~	~~252~~
	~~0~~	~~1~~	~~63~~	~~84~~	~~189~~
	~~1~~	~~0~~	~~161~~	~~98~~	~~140~~
	~~1~~	~~1~~	~~161~~	~~70~~	~~105~~

~~Table 4. Expanded lookup table for multiplication avoidance.~~

~~Note that the determination of the current picture structure is based on display rather than coding structure. For interlaced display, pixels from the current field and previous field are used in the calculations. For progressive display, pixels from the current frame and previous frame are used in the calculations.~~

3.2.2 Pixel level operations

The comfort noise pixel level operations use the same pre-stored Gaussian random number list and primitive polynomial generator as the film grain simulation. Three distinct primitive polynomial uniform random number patterns are used within the comfort noise generation process.

For SD resolutions, the pixel level operations are performed for all luma pixels, and the generated luma noise value is applied to both luma and chroma pixels. Let pic_width = $\text{PicWidthInSamples}_L$.

For HD resolutions, the pixel level operations are performed on ¼ of the pixels, using a 2x2 sub-sampling, and then the generated noise value applied to all pixels, using a 2x2 pel repeat. Let pic_width = $\text{PicWidthInSamples}_L >> 1$.

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The first uniform random number pattern $x_0(i, seed\_x_0(t))$ is initialized with a seed, $seed\_x_0(0)=3$, at the arrival of the comfort noise SEI message. At each new frame t the uniform random number pattern is initialized to $seed\_x_0(t)$ where $seed\_x_0(t)= seed\_x_0(t-1) + 2$.

The second uniform random number pattern $x_1(i, seed\_x_1(t))$ is initialized with $seed\_x_1(t)= seed\_x_0(t-1)$. This implies that $x_1(i, seed\_x_1(t))= x_0(i, seed\_x_0(t-1))$.

Two new numbers $UN_0(t,i)$ and $UN_1(t,i)= UN_0(t-1,i)$ are then generated from these two patterns as follows:

$UN_0(t,i) = x_0(i, seed\_x_0(t)) \% 32 - 16$
$UN_1(t,i) = UN_0(t-1,i) = x_1(i, seed\_x_1(t)) \% 32 - 16$

The third uniform random number generator, UN_f, is initialized to 1 at the beginning of each displayed frame and is used to generate a fixed noise image. This number generates offsets into the Gaussian_list[ ] to access a line of 8 random numbers using the following operations, where i increments for each 8 values:

$UN_f= x(i, 1)$
for n=0..7, $G[n] = (Gaussian\_list[(UN_f + n)\%2048] + 1) >> 1$

The noise value at position [r][s] of the noise image is computed as

$m = pic\_width*r+s$
$noise[r][s] = (w_f*G[s\%8]+ w_0*UN_0(t, m) + w_1*UN_0(t-1, m) + 512) >> 10$

where w_0, w_1, and w_f change at the block boundaries.

For SD sequences the final noise luma_noise is identical to noise, while for HD sequences the final noise luma_noise is generated by performing a 2x2 upsampling of noise using pixel repetition.

The chroma noise is half the value of the final luma noise
$chroma\_noise[r][s] = (luma\_noise [r*2][s*2] + 1) >> 1$

Finally comfort noise shall be added to the decoded pixels and the result shall be clipped within the range of [0, 255] for display.

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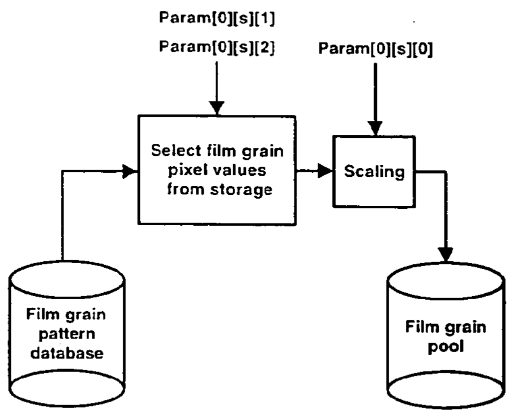

Figure 1. Film grain initialization process at SEI message receipt, performed for multiple blocks in each luma intensity interval

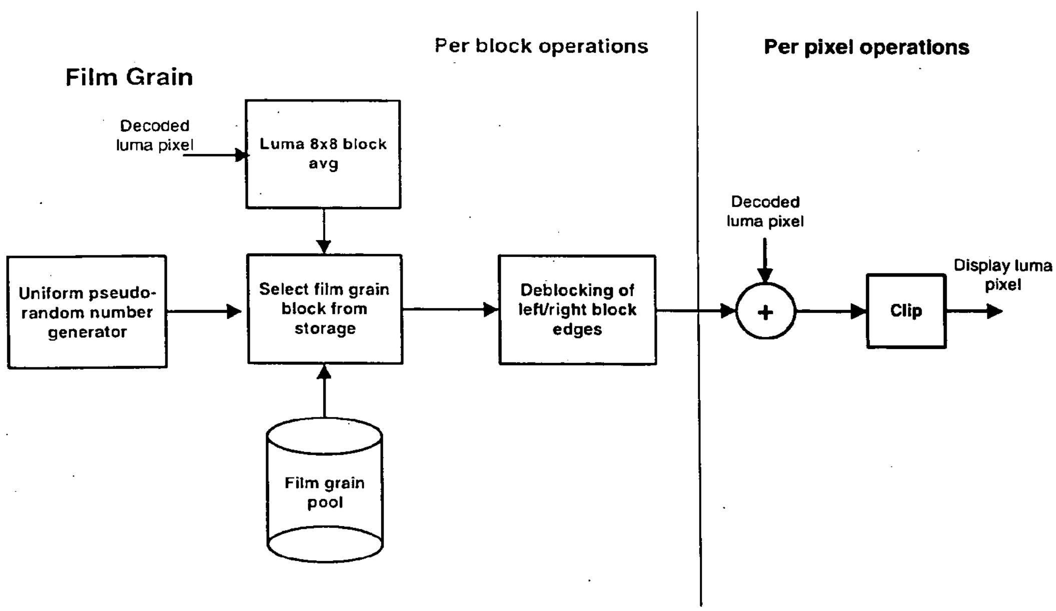

Figure 2. Film grain per block and per pixel operations

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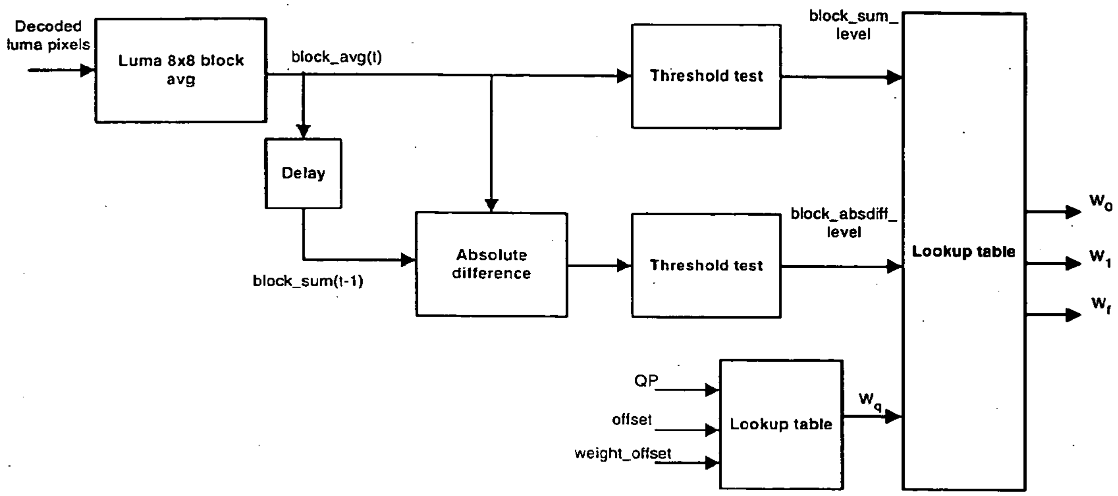

Figure 3. Comfort noise per block operations

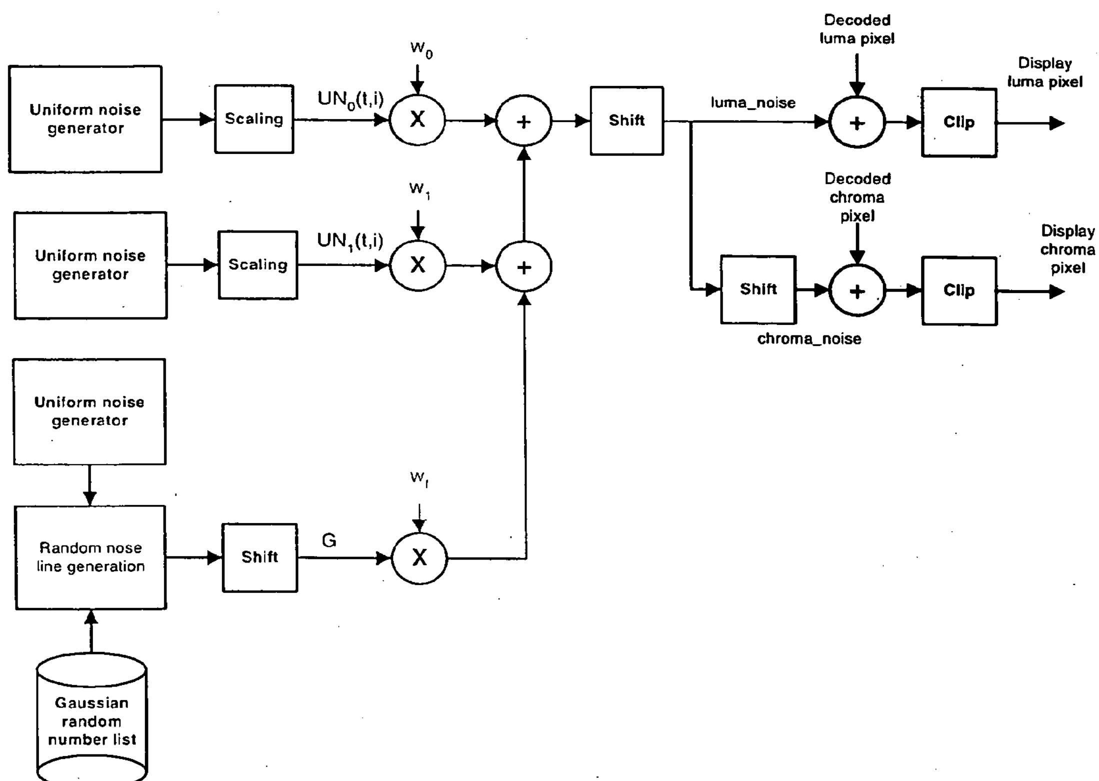

Figure 4. Comfort noise per pixel operations